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The Use of Biomarkers in Outdoor Education Research: Promises, Challenges, and the Development of Evidence

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Abstract

While widely used in research connected with outdoor education, self-report data can be subject to a number of issues related to validity and generalizability. This paper argues that biomarkers present another type of evidence that is equally or even more rigorous than self-report data. The paper describes several types of biomarkers that are commonly measured in other disciplines along with how data from those biomarkers are collected. Data from a recent study using two biomarkers commonly used for measuring stress is presented as an example of how the use of biomarkers can broaden the body of evidence being developed in outdoor education.

Keywords: *amalyse, biomarkers, cortisol, outdoor education, self-report data, validity*

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Introduction

While widely used in research connected with outdoor education, self-report data can be subject to a number of issues related to validity and systematic bias in the responses. Moreover, over-relying on one type of data collection such as self-reported data, calls into question the accuracy and integrity of the comprehensive body of evidence presented in the outdoor education literature. This paper argues that biomarkers present another type of evidence relative to the effect of outdoor education programs that is equally or even more rigorous than self-reports. The paper describes several types of biomarkers that are commonly measured in other disciplines along with how the data from those particular biomarkers are collected. Data from a recent study using two biomarkers (cortisol and amalyse) for measuring stress is used as an example of how the use of biomarkers can broaden the body of evidence being developed in outdoor education research.

Beginning with the formative works of scholars such as Vogl and Vogl (1974), Iida (1975) and Shore (1977), there exists a growing body of research suggesting that adventure and outdoor education activities can be associated with a wide variety of benefits to both individuals and groups of participants. With few exceptions, this corpus of information has been primarily developed through the use of instruments using self-report types of data (surveys, interviews, questionnaires, etc.) as the data collection formats. This paper explores the use of biomarkers as another source of data collection that offers a viable way to build the research-based evidence useful in describing the efficacy of outdoor education. Accordingly, this paper uses the following sequence of discussion: (1) the advantages and challenges of using self-report methods, (2) examples of biomarkers, (3) providing an example of outdoor education research using biomarkers through a recently completed study that used two biomarkers, cortisol and amalyse, and (4) the challenges and advantages attendant with using biomarkers

The Advantages and Challenges of the Self-Report

Self-report data collection typically refers to data collected via a paper and pencil, and now increasingly, laptop, tablet, or other electronic format, in which the respondent directly provides answers to the stated questions. These responses can also take the form of verbal statements commonly seen in qualitative methods such as semi-structured interviews. As evidenced by the popularity of the self-report, this method of collecting data has a number of advantages. Depending on the questions or information sought, self-reports can be a highly efficient way of collecting large amounts of data and variables (Del Boca & Darkes, 2003). Widespread use of self-report data extends far beyond outdoor education and includes a wide variety of disciplines including edu-

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cation, psychology, business, and management (Donaldson & Grant-Vallone, 2002). Moreover, self-reports offer the means to assess a wide variety of types of information including the following (Podsakoff & Organ, 1986):

- Demographic and other types of factual data (e.g., age, sex, education level, etc.).
- Personality data (e.g., anxiety level, locus of control, self-efficacy, etc.).
- Descriptions of past experiences, participant behaviors, intentions for future behavior, etc.).
- Psychological constructs such as attitudes, beliefs, motivations, etc.
- External variables such as weather, instructor qualities, group effectiveness, etc.)

Clearly the self-report offers a number of advantages for specific types of research. In addition, the self-report offers respondents opportunities to reflect and consider their responses, often in a more naturalistic and timely manner rather than the laboratory or traditional classroom setting which can be viewed as relatively artificial. Thus, for a wide variety of outdoor education settings and for a broad spectrum of questions, the self-report can provide timely and useful information.

Despite these advantages, the self-report has a number of disadvantages that need to be considered and taken into account by the outdoor education researcher. The following section discusses these disadvantages.

Disadvantages of Self-Report Generated Data

A number of issues can be associated with data generated from self-report formats. Response behaviors are often influenced by a complex interaction of social context, characteristics of respondents, and task attributes, including difficulties associated with answering the questions (Del Boca & Darkes, 2003). For example, *acquiescence* implies that responses are made with little thought as to the most accurate feelings or beliefs held by the respondent. Related to this concept is *social desirability* in which respondents report on a particular questionnaire or interview item in a manner they feel is most socially acceptable, as opposed to how they may really feel or believe (Diers, 1964; Ferrando & Anguiano-Carrasco, 2010).

Somewhat related to the issue of social desirability are the constructs of *demand characteristics* and *reactive arrangements*. A demand characteristic is present when respondents provide answers in line with what they believe the researcher wants (Pyrczak, 2013). In reactive arrangements, the respondent knows they are participating in a study, which often represents an artificial setting and hence, the answers really do not matter (Campbell & Stanley, 1963, p. 20).

Finally, notwithstanding the above disadvantages just described, there is another equally important factor that influences self-report data, namely, accuracy. That is, there may be occasions when respondents simply do not know how they feel, remember how they felt, or what they believe about a particular issue or item. This fact, coupled with potential time, weather, schedule, or location pressures often present in outdoor education settings, can lead to hurried or incompletely thought through responses.

In sum, within the outdoor education setting, the self-report can be useful in certain situations but does present a number of challenges in demonstrating accuracy. These factors, combined with the fact that the preponderance of research studies done in outdoor education involves self-report data, presents potential questions relative to validity and reliability directed at the findings associated with outdoor education experiences. Another approach to collecting data that can complement self-report data is biophysical-based and represents another type of data that can be useful in the outdoor education setting.

Types of Biomarkers

From a medical perspective, biomarkers can be considered a measurable substance in an organism whose presence is indicative of some phenomenon such as disease, infection, or environmental exposure. Common examples of biomarkers used in medicine include heart rate, respiration rates, skin conductance, and various enzymes, proteins, and hormones. In adventure and experiential education (AEE), biomarkers have most often been used to measure phenomenon such as anxiety, stress, and excitement. Examples of biomarkers used in AEE include blood pressure, cortisol, epinephrine, and norepinephrine.

While sometimes necessitating specialized equipment or facilities, biomarkers represent data that are inherently personal, not subject to issues such as social desirability and recall, as well as being more amenable to precise measurement. Thus, the use of biomarkers in studying AEE types of settings and programs presents the researcher with an additional set of data that represents potential changes in the body chemistry that may or may not be congruent with what the respondent is reporting.

For example, levels of anxiety can be measured via a number of self-report instruments such as those developed by Spielberger (1983). In one study, Noto, Tetsumi, Mihoko, Kiyoshi, and Kazuyoshi (2005) found a strong relationship between one commonly used biomarker, amalyse, and self-reported levels of anxiety. In this study, both the self-report and biomarker values augmented each other to provide a higher level of confidence that levels of anxiety were being measured accurately. The assumption underlying the use of biomarkers is that biomarkers can often point to an individual's physiological state, even though a self-report mechanism may indicate something else. Thus, biomarkers can serve useful roles as a complementary set of data to the self-report or

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other data forms, or as a stand-alone data source, depending on the research design. The following section describes several biomarkers that are either currently used or have applicability to research in outdoor education.

Cortisol

Cortisol is a steroid hormone belonging to a broader class of steroids called glucocorticoids that are produced by the adrenal glands and secreted during a stress response. The psychobiology of the stress response involves a perception of stress by the individual that activates the hypothalamic-pituitary-adrenal (HPA) axis that results in the secretion of glucocorticoids such as cortisol in the circulation. The primary purpose of cortisol is to redistribute energy (glucose) to high priority parts of the body such as the heart, brain, and muscles and is often associated with the concept of fight or flight. However, detrimental changes occur in the body if heightened levels of cortisol are present for extended periods of time, including the suppression of the immune system. These negative effects are often associated with the term "chronic stress" and are linked to the body's response to extended exposure to cortisol. Levels of cortisol are typically measured through samples of blood or saliva and must be frozen shortly after collection to preclude deterioration of the hormone. Gordis, Granger, Susman, and Trickett (2006) report that cortisol levels peak approximately 10 minutes after post-stressor and return to baseline within 20 minutes of post-stressor (that is, following the stressful event). Cortisol is also subject to diurnal variation with, in the absence of a stress response, peak levels of cortisol being observed in early morning and lowest level late at night (de Weerth, Zijl, & Buitelaar, 2003).

Alpha-Amylase

Alpha-amylase (A-A) is a protein enzyme that breaks down large polysaccharides such as starch and yields high-energy glucose and maltose. Amylase is found in saliva and is secreted through activation of the sympathetic nervous system (SNS) often in response to events related to stress and perceived threat (Koibuchi & Suzuki, 2014; Nater & Rohleder, 2009). That is, by rapidly breaking down starches to sugars, easily accessible energy can be redistributed to parts of the body involved in the flight-or-fight syndrome such as muscles, heart, and brain. Amylase is typically measured through samples of saliva and is thought to be a useful indicator of activity within the sympathetic nervous system (e.g., heart rate, pupil dilation, increased perspiration, etc.). In addition, A-A reacts and recovers more quickly from the stress event than does cortisol, usually returning to baseline within 10 minutes post-stressor (Gordis et al., 2006). In addition, A-A can also be affected by exercise and physical stress.

Epinephrine

Epinephrine, also known as adrenaline, is both a hormone and neurotransmitter and, like cortisol, is secreted by the adrenal glands. Epinephrine is linked to increased activation of the sympathetic system (e.g., heart rate, respiration rate, blood pressure, etc.) and is often associated with the flight-or-fight response (Pearce, 2009). In addition, it increases the rate of metabolism and bronchodilation. This bronchodilation effect is how most outdoor educators have come in contact with epinephrine through the use of epi-pens and the serious potential emergency of anaphylaxis. Typically, the greater the physical and emotional demands placed on the body, the greater the resultant levels of epinephrine. Interestingly, some evidence suggests that higher levels of epinephrine or norepinephrine may be associated with higher levels of negative feelings experienced by an individual and decision-making processes (Eisenberger, Lieberman, & Williams, 2003; Nieuwenhuis Aston-Jones, & Cohen, 2005). This effect can be partially explained by the physiological sympathetic responses such as increased heart and respiration rate. For example, an individual feels a higher heart rate, dry mouth, or increased respiration and then "feel" afraid. In addition, epinephrine has also been associated with increased memory of emotionally stressful events, particularly fear, thus providing a survival advantage by helping ensure the individual "remembers" stressful events (Mezzacappa, Katkin, & Palmer, 1999). Epinephrine is typically measured through blood or urine samples.

Norepinephrine

Norepinephrine, also known as noradrenaline, is a hormone and neurotransmitter often associated with an increase in vigilant concentration. Along with epinephrine, norepinephrine underlies the fight or flight response with increasing heart rate, release of glucose, increased blood flow, and faster respiration rates. Like epinephrine, there is some evidence that norepinephrine activates the brain in a way that increases issues such as pattern recognition or intensifying the attention span. Moreover, fasting up to four days is thought to increase levels of norepinephrine (Zauner et al., 2000), which may have some implications for the extended solos used in some outdoor education programs that involve fasting. Norepinephrine is measured through samples of the blood or urine.

In sum, with the exception of amalyse, which is an enzyme, cortisol, epinephrine, and norepinephrine are hormones strongly associated with high stress and perceived danger commonly characterized as the fight-or-flight syndrome. Two disadvantages associated with research using these types of biomarkers are (1) measurement of these data require laboratory analyses and (2) each type of biomarker necessitates collection and specific handling of saliva, blood or serum, or urine. The following section describes several non-chemical biomarkers that can be useful in outdoor education research settings and generally only require a specific mechanical measuring device.

Electrodermal Activity

Electrodermal activity (EDA) is more commonly known as skin conductance or galvanic skin response. The theory underlying the use of this approach is the process in which the sweat glands in the skin are controlled by the sympathetic nervous system (Martini & Bartholomew, 2001). If an individual is highly aroused, sweat gland activity will increase with a corresponding increase in electrical skin conductance between two points over time. Thus, EDA becomes a measure of emotional and sympathetic activation. EDA measurements are responsive to emotions such as fear, anger, and startled responses.

Heart Rate and Heart Rate Variability

Heart rate (HR) is the speed of the heartbeat measured over a unit of time. Heart rate variability (HRV) measures the variation in the time intervals between heartbeats. HRV is affected by variables such as thermoregulation, hormones, sleep-wake cycles, physical activity and stress. In addition, HRV may be particularly susceptible to issues often present in outdoor education settings such as time pressure and emotional strain (Jönsson, 2007).

Like HRV, heart rate (HR) is also influenced by the sympathetic and parasympathetic nervous systems (Hall & Guyton, 2005). Factors that are commonly associated with changes in HR and often involve outdoor education situations include: emotional challenges, anxiety and fear, anticipated and actual physical activity, increases in epinephrine and norepinephrine, thermoregulation issues, nicotine, caffeine, and anticipation of relaxation and/or rest.

Blood Pressure and Respiration

Along with heart rate, blood pressure (BP) and respiration (R) are commonly recognized indicators of an individual's health within outdoor education settings. Along with HR, oxygen saturation, body temperature, and level of consciousness (LOC), blood pressure and respiration comprise the vital signs of a body. Within an outdoor education experience, both blood pressure and respiration are influenced by a variety of variables such as activity demands, environmental conditions, emotional state, stress, diet, certain drugs, alcohol, and inputs from the endocrine system. While measurement of respiration rates is fairly self-explanatory, new advances in technology have provided for relatively easy and fairly accurate measurement of blood pressure without the use of sphygmomanometers and similar types of devices. Moreover, both blood pressure and respiration can be useful in determining changes in the individual's emotional and physical states without the uncertainty and imprecision of self-reports.

Using Biomarkers in Research

In what ways can biomarkers augment and complement the data collection process in outdoor education? To date, there are only limited studies that have evaluated biochemical responses in outdoor education. For example, Bunting, Tolson, Kuhn, Suarez, and Williams (2000) collected urine and saliva samples to examine participants' physiological stress responses during different adventure tasks. Their findings indicated that participants recorded the highest urinary neuroendocrine responses during the advanced rock climbing and whitewater canoeing days. In addition, people with lower fitness levels have shown greater stress responses toward stressful tasks. Similarly, Coetzee (2011) found increased stress levels as measured by cortisol and heart rate variability among beginning scuba divers enrolled in a training course.

In the following example, two biomarkers, cortisol and amalyse, are used to ascertain changes from visitation to a natural environment. From an outdoor education perspective, the specific research question focused on whether visitation to a park or similar natural setting could be effective in reducing levels of stress (Ewert, Klaunig, Wang, & Conklin, 2014). Study participants were asked to provide 3-5 ml saliva samples just prior to the start of their park visitation and immediately following the conclusion of that experience. The length of park visit was approximately 30-120 minutes with the participants primarily consisting of adults, ranging in age from 19 to 56 years old, with females and males fairly evenly split, and either individuals working or attending the local university. Park visitors who had just eaten were eliminated from the sample pool to reduce the effect of recent food intake upon cortisol and amalyse levels. The samples were marked and stored frozen for later evaluation. Cortisol was measured by ELISA techniques using a TECAN multi-plate reader. The sampling time frame is in accordance with that posited by Barker, Knisley, McCain, and Best (2005), which suggested that the optimal time for measuring salivary cortisol levels was within a 45-minute time period following the activity. Because salivary cortisol levels are particularly subject to variability in the early morning awakening hours, only those respondents arriving to the study sites after 10:00 am were tested. The amylase activity was measured using a salivary alpha-amylase assay kit, a commercial enzymatic assay specifically designed to measure this enzyme in humans.

From a sample of 47 respondents (26 female, 21 male) and using a repeated measures pre/post design with paired sample *t*-tests, results indicated a significant reduction in levels of cortisol (See Figure 1). In addition, the duration of visit variable was significantly associated with a reduction in cortisol ($p = .049$). This pattern of decreasing levels of cortisol from the pre-visit was demonstrated for both males and females (See Figures 2a and 2b). On the other hand, amalyse levels increased between pre-visit and post-visit times for both males and females (See Figures 3a and 3b). Similar to cortisol measurements, the pattern for increased levels of amalyse at the post-visit time persisted for both males and females (See Figures 4a and 4b).

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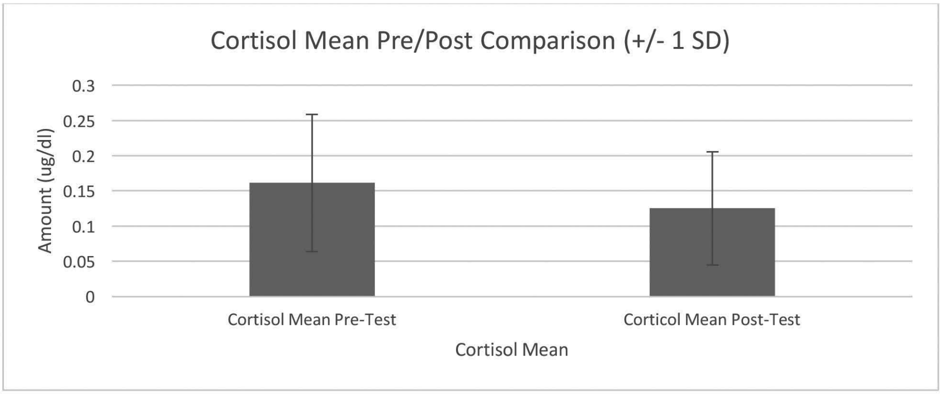

* Significant at $p < .05$.

Figure 1. Total Cortisol Sample Comparison*

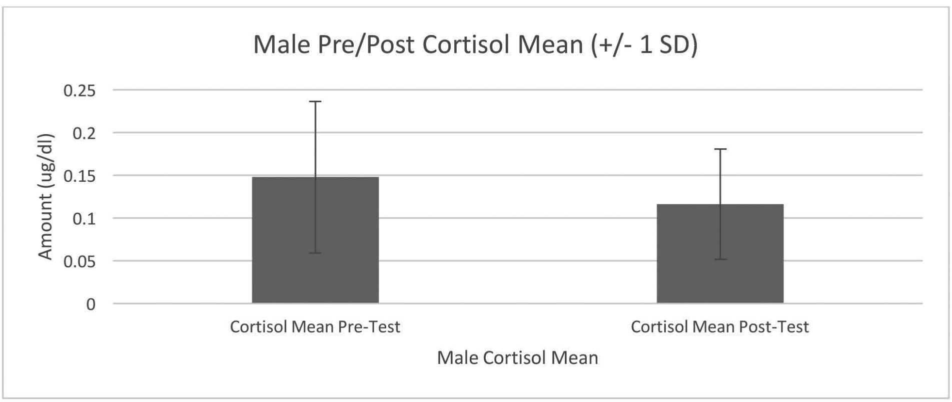

Figure 2a. Male Cortisol Levels Over Time

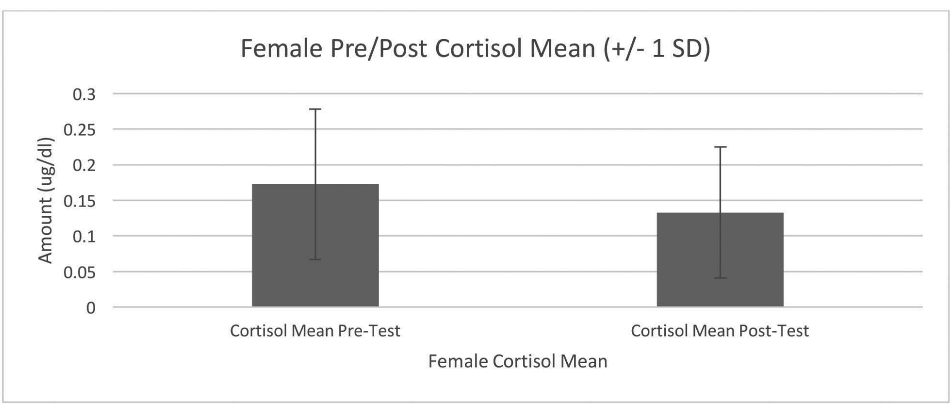

Figure 2b. Female Cortisol Levels Over Time

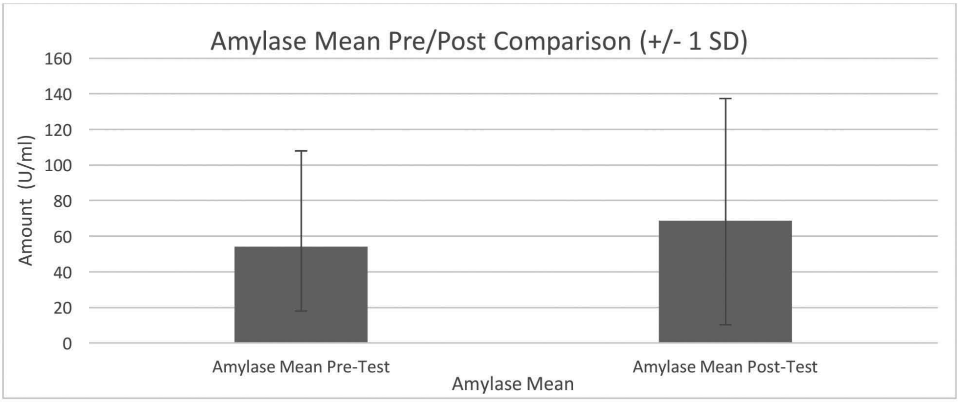

Figure 3. Total Amylase Sample Comparison

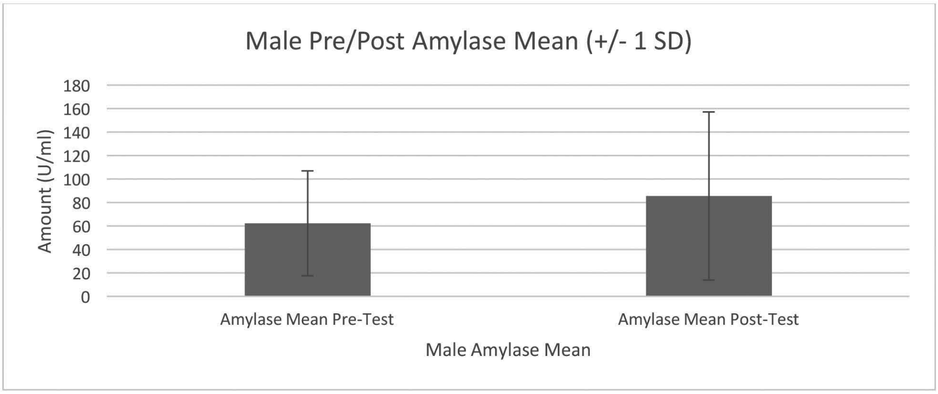

Figure 4a. Male Amalyse Levels Over Time

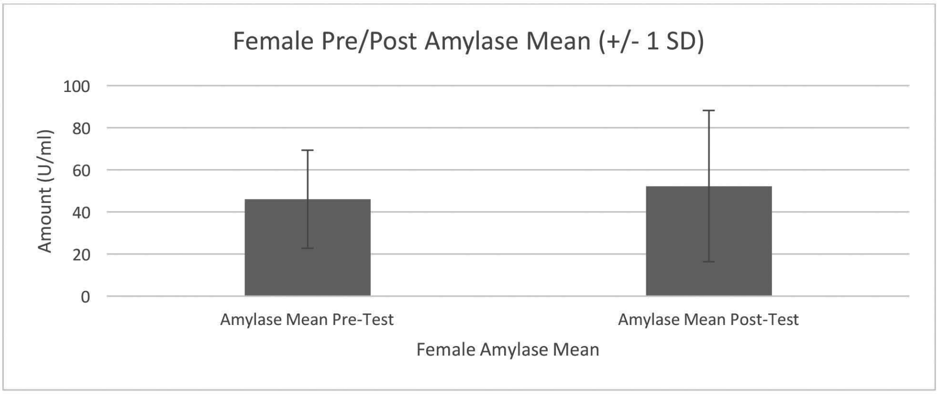

Figure 4b. Female Amalyse Levels Over Time

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It was concluded that visitation to an outdoor setting can be effective in creating a psychological sense of well-being as expressed through reduction of stress levels as measured by cortisol. However, also recognized was an increase in amalyse when comparing the pre and post visit levels. So why the difference between cortisol and amalyse? It is here where the use of biomarkers can provide some useful insight not typically identified by questionnaires and other self-report methods. A growing body of information suggests that amylase reflects activity from the sympathetic nervous system such as heart rate, blood pressure, digestive tract, and respiration (Nater & Rohleder, 2009). Further, Yamaguchi, Deguchi, and Miyazaki (2006) report that exercise in natural areas can stimulate the sympathetic nervous system and result in increases in levels of salivary amalyse. Thus, the increase in amalyse reported in this study may represent a manifestation of the physical demands placed on the respondent's body as they walked through and engaged in the natural setting. In this case the body may experience some form of "activation" through the physical components of the experience.

On the other hand, when compared to amalyse, cortisol is often more associated with the parasympathetic nervous system in addition to the sympathetic nervous system (Gordis, et al., 2006) and as such, may be more amenable to the sense of relaxation and catharsis presented to the individual through outdoor education types of experiences such as being engaged in a natural setting through hiking or educational activities. Thus, in the case of outdoor education, visitors to natural environments may be experiencing the dichotomous situation of experiencing a reduction in levels of stress while concomitantly also experiencing an activation of systems needed to physically engage in the activity. The use of biomarkers can provide useful information in the development of our understanding of the distinction made between a threat and a challenge.

Other Possibilities in the Use of Biomarkers

Also intriguing is the question raised by Kemeny (2003), which asks if there is a difference between threat and challenge to the respondent when engaged in activities similar to those present through outdoor education. According to Blascovich and Tomaka (1996), an event is perceived as threatening when the demands of a situation outweigh the available resources. When the resources are deemed to be equal to or exceed the demands, the individual experiences a challenge. In a sense, challenge represents potential for growth, a sense of novelty, and an opportunity to extend personal limits (Tsau, Lin, & Cheng, 2015). Conversely, threat represents a potential for harm or loss, and is generally viewed as a negative event (Bunting et al., 2000).

These two perceptual states (threat or challenge) are associated with distinctive responses in the autonomic nervous system. For example, challenges often result in increases in sympathetic arousal such as increased cardiac performance along with a reduction in blood pressure. In contrast, a perceived threat is also often associated with increased cardiac performance such as increases in heart rate, but is distinguished from perceived challenge by an increase in blood pressure (Seery, 2011). While still relatively unexplored, the use of biomarkers may be an important way to distinguish between an individual's perception of an outdoor education activity or experience as either being a threat or a challenge.

Thus, the difference between both challenge and threat can represent an important distinction in outdoor education. A question that is worthy of staff having answers to is whether students are having a challenging experience or one that poses a threat during an outdoor education activity. The use of biomarkers can provide the means to better understand this distinction.

Concluding Comments on the Use of Biomarkers

Clearly there are certain types of data and information that can be collected through the use of biomarkers that cannot be garnered through other forms of data collection that are more traditionally used in outdoor education, such as self-report questionnaires. Some of these data represent information that is not fully recognized via cognitive processes such as anxiety, stress, dread, and perceptions. Also, just as clearly is the reality that, particularly with respect to the catecholamines discussed in this paper such as cortisol, specialized laboratory settings and trained people are required as well in addition to somewhat fixed procedures (e.g., freezing samples shortly after collection, etc.). In addition, while not requiring laboratory settings, biomarkers such as heart rate, blood pressure, or skin conductance do necessitate the use of specialized equipment, and testing materials are now small in size and cost. It should also be noted that Yamaguchi et al. (2006) report successful data collection for amalyse using a hand-held monitor.

In addition, biomarkers such as cortisol, amalyse, norepinephrine, and epinephrine are primarily associated with stress or similar flight or fight responses. Missing from the literature associated with outdoor education is any mention of hormones or other body indicators such as serotonin and dopamine that can result from a positive or enhancing situation. To date, no literature was found that speaks to the production of these types of biomarkers from the positive experience of outdoor education.

From a logistical perspective, several questions arise in the use of biomarkers in outdoor education research. If the researcher is using catecholamine-based or similar types of biomarkers, a laboratory analysis will need to be done. Within this context, what lab should be used?, where can it be found?, and what will the analysis cost are appropriate questions. Typically, universities often have laboratories that can handle this type of analysis and relatively low-cost lab kits can be purchased with which the analysis is performed.

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Within the field setting itself, samples of saliva, urine, or blood will need to be either chilled or frozen to prevent deterioration of the biomarker. Moreover, depending on the biomarker, certain limitations will need to be followed. For example, time of day, recent input of food or water, and level of physical activity can serve as confounding variables and should be considered before data are collected.

In the vast majority of cases, questionnaires, interviews, and other self-report types of instruments will continue to be the instrumentation of choice. The point of this paper is to illustrate some other types of data that present an alternative perspective on what is happening to students in outdoor education and people engaged in natural settings. In conclusion, biomarkers present another type of data that can be useful in the outdoor education. While not all research efforts have the advantages of functioning laboratories and training lab personnel, most researchers in outdoor education are university-based and may have access to these types of resources. Using these types of resources would provide the field with a host of more integrative studies involving other disciplines such as biology, epidemiology, and public health. This, in itself, would provide for a more comprehensive body of evidence within the field of outdoor education.

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